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The trouble with 'women in computing': a critical examination of the deployment of research on the gender gap in computer science

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ABSTRACT

The pessimistic scenario for 'women in information communications technology' and for 'women in technology' generally is even more paradoxical and insidious with respect to 'women in computing'. Studies within this field not only report insignificant improvement in the proportion of women in Western countries' computing fields but also alert us of a declining trend. Moreover, that decline has been accompanied – or even preceded – by years of research and programs that have specifically focused on increasing women's participation in computing; however, they have not had the expected effect. More surprisingly, there has been a significant increase in the representation of women in all other science-related fields and professions. Our aim is to provide some clues to fight the feeling of inexorability that may be entailed by the research on women in computing. We will argue that part of the problem is related to the static nature of the research deployed around the problem of 'women in computing', primarily, the research constructed around the 'leaky pipeline' metaphor. We provide a synthesis of the critiques this research has received in recent decades and highlight research trends that render other landscapes visible when studying 'women in computing'. These trends help us question how we are conducting research within this field and urge us to problematise assumptions about computing and gender that we may paradoxically continue to reproduce even while denouncing the paucity of women in computing and studying the reasons for this state of affairs. In short, we present the need for different researchers' eyes that allow different landscapes of women and computing to be seen and produced.

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Introduction

> The only true voyage of discovery (…) would be not to visit strange lands but to possess other eyes. (Marcel Proust)

Recent decades have seen the establishment of 'women in computing' as a subject of study. The low proportion of women in computer science, computer engineering and informatics in countries such as the United States, Canada, the members of the European Union, New Zealand and Australia has been well documented in numerous reports, papers, magazines and newspapers articles. Indeed, the situation continues to be documented, showing each year that the proportion of women entering computing and information technology (IT) degree programs not only fails to increase – it declines.

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As Cohoon and Aspray stated in 2006 regarding computing education in the US, 'We have to face the fact that twenty-five years of interventions have not worked' (Cohoon & Aspray, 2006, p. ix). This pessimistic landscape becomes even darker upon adopting the perspective of Caroline C. Hayes: 'If this trend were to continue at the rate experienced from 1986 to 2006, there will be no women bachelor's degree graduates in computer science by 2032' (Hayes, 2010a, p. 27).

In either a tacit or an explicit way, this under-representation is presented as a paradoxical phenomenon. Concerns about 'women in computing' have continued to grow even in a decade in which multiple studies from Western countries show an increasing number of women accessing new information and communication technology (ICT) (CERI, 2010; European Commission, 2010; Faulkner & Lie, 2007). Although those studies continue to report a gender gap in terms of some specific skills, the general trend indicates that this gender gap is not far from being closed. However, there has not been an effective incorporation of women into the educational and professional worlds of ICT. Thus, as Faulkner and Lie (2007) synthesise, 'The overall picture is a contradictory one: optimistic with respect to what we call women and ICT (that is, women as users) and pessimistic with respect to women in ICT (that is, women within the ICT professions)' (Faulkner & Lie, 2007, p. 158).

Not surprisingly, along with this distressing scenario, the question 'Why are there so few female computer scientists?' (Spertus, 1991) has almost become a field of study in its own right. Indeed, this key interrogation seems to have undergone little change during the last decade, as shown by the following list of works: 'Why we are losing women in the CS field' (Gürer & Camp, 2002), 'Why do so few women major in computer science?' (Beyer, 2006), 'Why are girls still not attracted to ICT studies and careers?' (Gras-Velazquez, Joyce, & Maïté, 2009), 'Computer Science: where (and why) have all the women gone?' (Ross, 2010), 'Why so few women enrol in computing?' (Varma, 2010b), 'Why females do not choose computing' (Laosethakul, & Leingpibul, 2010), 'Why aren't more women in computer science?' (Whitecraft & Williams, 2010) and 'Why women and minorities are underrepresented in the computer science major' (Bock, Taylor, Phillips, & Sun, 2013). The persistence of the same question for years reinforces a feeling of 'stability' (Corneliussen, 2012) or even inexorability related to the topic of women in computing.

According to a common metaphor, a girl should be entering the pipeline of computing when she enters school, by taking preparatory courses, becoming experienced in the use of computers and thus becoming prepared for undergraduate college degrees in computer science. Further along the pipeline – and depending on the educational system – a young woman would major in computer science and after that, she would graduate from a computing discipline. At the end of the educational pipeline – with a bachelor's, master's or doctoral degree in computing – this woman would enter the workforce pipeline, advancing from entry-level positions to more senior positions in the computing field (Bartol & Aspray, 2006b). However, as data show, this pipeline leaks in every junction in almost every western country.

In this article we will critically examine the research on this topic to show how this monotonous western landscape does not change because mainstream research does not question basic assumptions about 'what is computing' and 'what is gender', which frame and feed the problem. To do so, first of all we will present the dominant framework in research on 'women and computing' – the 'leaky pipeline' metaphor – we will trace the history of the metaphor to show the gaze which produced it, and then we will present the main critiques of this framework. Finally, we will present four new 'landscapes' that emerge in front of our eyes if we change the 'leaky pipeline' metaphor that we live by as researchers, and that show that women have been and are actively participating in computing: historical landscapes, non-western landscapes, intersectional landscapes and joyful landscapes.

Researchers' eyes: Why do girls not enter the pipeline?

The dominant framework that seeks to explain the fact that women are under-represented in computing, – and in science, engineering, technology and mathematics (STEM) fields in general – is usually condensed through the metaphor of a 'leaky pipeline'. This metaphor encourages us to see a pipeline carrying students through different educational stages (school, university, masters and so on) to high

positions in STEM, in academia or in industry, and to characterise the problem as a flow of girls/women diminishing over the stages (Soe & Yakura, 2008). Thus, research is primarily focused in exploring why girls or women do not enter into the IT educational pipeline and why they do not persist, advance or remain in the field (Bartol & Aspray, 2006a, 2006b; Cohoon & Aspray, 2006). What those studies have in common is the aim to identify the factors that explain the leaking at each transition point (From high school computing courses to post-secondary computing education and then the progression in the IT academic world and/or within the IT sector/professions.). Thus, the pipeline model is primarily used to quantify the flow of people who move through different transition points or junctions along this path and to look for trends that are specific to women and minorities. One of its most important contributions has been to highlight that the further along the pipeline we look, the fewer women we find. At each transition point, from one educational or career stage to the next, the pipeline narrows and 'loses' people. Specifically, the research shows that at each stage, the pipeline 'leaks' more for women than it does for men. The field of computer science has even been qualified as the 'incredible shrinking pipeline' (Camp, 1997) to highlight that in addition to leaking at transition junctions, the ratio of women becomes smaller at every stage of a computer science career, including at the bachelors' level and therefore in the job market. Furthermore, in western countries, the ratio of women has been shrinking for three decades.

Most of the research indicates that middle school is a key moment of 'exclusion' and 'disaffection' formation because by high school, gender differences in computing interest (and thus, girls' lack of interest in computing or IT as a career option) are well established. Thus, there is a set of well-established topics that explore both the direct factors that explain why girls avoid studying computing subjects in high school and/or choose not to enrol or major in computing at the university level and also a set of topics to study girls' involvement with IT and how that involvement can impinge on an 'exclusion' pathway into IT careers.

With respect to the common psychological explanations for why girls avoid computer-related subjects, research usually agrees on four specific aspects: (a) the image and stereotypes of computer scientists and people in computer science as awkward, nerdy males who lack interpersonal skills and are obsessed with technology; (b) the related image of computer science as a male-dominated arena oriented towards working not with people but with 'machines'; (c) the poor knowledge and awareness of computer science as a discipline and as a career; and (d) the perception of computer-related subjects as unattractive and/or boring (Anderson, Lankshear, Timms, & Courtney, 2008; Banerjee & Santa Maria, 2013; Grant, Knight, & Steinbach, 2007; Papastergiou, 2008; Rommes, Overbeek, Scholte, Engels, & De Kemp, 2007; Sáinz, 2011). Although computer science as a profession does not seem to be a generally attractive choice, those stereotypes, images and perceptions are regarded as a deterrent that is more important to and/or more damaging for girls than for boys (Fisher & Margolis, 2003; Lang, 2010).

In addition, a common set of social factors is regarded as the key influencers of a girl's choice 'against' a computing or IT career. First, there is an important body of research focused on the study of agents of socialisation that may influence girls' (lack of) choice to go into computing (Adya & Kaiser, 2005; Bartol & Aspray, 2006a; Cohoon & Aspray, 2006). Within this area, there are studies that explore how family (particularly parents) influence or motivate career choice (either directly or indirectly) not only by encouraging girls to pursue other studies or not to pursue computing but also by transmitting stereotypes about girls' lack of capability with respect to ICTs in general (Babin, Grant, & Sawal, 2010; Vekiri & Chronaki, 2008; Vekiri, 2010). Peer pressure to conform to stereotypical roles has been also considered to influence this (lack of) interest (Cohoon & Aspray, 2006; Robnett & Leaper, 2012). Also a line of research looks for the direct or indirect contribution of media, popular culture, media representations and advertisements to explain girls' lack of interest in or desire for computing careers (Cheryan, Plaut, Handron, & Hudson, 2013; Sele, 2012). Again, the main point is that the media's marginal representation of females in computing or technology and the media's role in disseminating gendered representations about computing professions and/or computing in general creates a situation in which girls (and their parents and peers) learn that those professions do not match their gendered identity and are not shown the necessary roles to emulate.

A significant body of research is devoted to 'structural factors', including formal education-related factors, computer access and computer use (Adya & Kaiser, 2005; Bartol & Aspray, 2006a; Cohoon & Aspray, 2006). On the subject of formal education, along with indicating general deterring factors such as the inadequate content of computing curricula and computing teaching practices at school, the research addresses teachers' training, interests and views about both computing and computing professions. In particular, the research focuses on teachers' perception of computing as a profession/career for boys more than for girls as an important factor to understand the lack of support for girls who choose computing education and career paths (Bartol & Aspray, 2006a; Meelissen & Drent, 2008; Sáinz, Pálmen, & García-Cuesta, 2011; Varma, 2010b; Vekiri, 2010). Although the area of computer access and usage was once one of the biggest areas of research (Bartol & Aspray, 2006a), the general increase in the availability of computers in both schools and homes has led researchers to study more precisely the amount of time spent with computers and the type of usages, which may influence whether a girl opts for computer-related studies (Downes & Looker, 2011).

Finally, a related (and massive) area of research is the study of gender differences in computer attitudes, which are widely assumed as key predictors of the intention to pursue computer-related studies and occupations (Adya & Kaiser, 2005; Anderson et al., 2008; Bartol & Aspray, 2006a; Sáinz & López-Sáez, 2010). The common statement in such studies is that boys have more positive computer attitudes than girls and therefore that they will have higher interest and expectations related to enrolling in computer-related studies. In this regard, those studies suggest that girls do not have such positive experiences with IT: Their relationship with IT becomes problematic during adolescence, although it begins earlier. Those studies show that boys usually have fun with computers, see them as toys and have a special interest in the 'technical' and 'mechanical' aspects of computers. Conversely, girls are deemed to view and use computers more instrumentally – as a 'mere' tool – and are more interested in computers' communication possibilities. The literature links this lack of enthusiasm towards computers to a low trust in their own skills: girls systematically undervalue their technological skills compared to what they really know and show much less trust in themselves. Thus, along with highlighting girls' less-positive computer attitudes, there is also a consensus about girls' lower 'computer self-efficacy' (Meelissen & Drent, 2008) as a factor linked to their avoidance of computing studies.

Whose eyes?

According to Lucena's research (Lucena, 2000), the National Science Foundation (NSF) invented the pipeline metaphor in the mid-1980s to explain to the nation the number of scientists and engineers that would be needed to insure both economic and military competitiveness through technological innovation and development. In the context of predicting a mass shortage of (white male) scientists and engineers in the near future, the NSF used the metaphor to highlight other categories of people (i.e. women and minorities) on whom to rely to fill the science and technology pipeline.

This metaphor, embedded into the discourse of economic competitiveness, offers a view of women and other (racial) minorities as statistical categories for policy makers who need to recruit and retain a techno-scientific workforce composed of people other than white males. Thus, the pipeline metaphor and model became an *apparatus* of knowledge and policy production, articulating what Lucena calls the 'pipeline industry': 'federal funding in exchange for the production of science and engineering students by educational institutions through recruitment and retention programs for women and minorities' (Lucena, 2000, p. 12). In this context, both the federal government and industry-sponsored offices, programs and strategies study and fix 'leaks' in the flow of women and minorities along the educational pipeline. Moreover, 'Where past invocations that it was just and right to foster the development of women and minorities in science had failed, the pipeline metaphor proved to be an extremely powerful way to link the under-representation of people in these groups to issues of national competitiveness in science and engineering' (Hammonds & Subramaniam, 2003, p. 939). Following Metcalf's (2010) condensation of this logic, the pipeline's discourse works as follows: Computer science and IT have a shortage of workers (white, male, national citizens), putting nations at a competitive risk. Women, people of colour and other

minorities are populations of 'untapped' resources. As this scholar synthesises, 'The view of women and people of colour as passive resources to be harnessed not only ignores agency, but it also hides the ways in which certain populations are disciplined, produced, and used for the benefits of others' (Metcalf, 2010, p. 3). Thus, this type of less-spread work allows us to think not only about the 'effectiveness' of our research (whether it measures things correctly, or whether it helps to increase women's numbers) but also about the epistemological, political and ethical nature of the eyes we have to see.

As Faulkner comments, '[t]he market has not generally proved a very innovative mechanism for improving gender inclusion in the information society' (Faulkner, 2004, p. 3) because we cannot separate gendered relationships to computing from the network of economic and social relations that build them. This should make us think about the cynical nature of the deployment of research on the gender gap, that is, women's importance in computer science solely as a 'reserve' labour force when there is or could be a shortage of (talented) white, middle-class men (Björkman & Trojer, 2006). Moreover, the fact that the argument for getting more women into computing and IT is quite often made in economic terms that relating directly to industry shortages (Adam, 2005) should make us aware of the importance of reviewing which and whose eyes we are using to define 'women in computing' as the problem. Instead of the increasing emphasis in considering gender and other 'diversity' categories as a factor in optimising efficiency and increasing productivity in the IT business and thus viewing inequality as a problem of 'wasted resources' (Trauth & Howcroft, 2006) or a loss of capital that 'threatens' competitiveness (Ashcraft, Eger, & Friend, 2012), we should instead see inequality as an ethical and political issue. Many women's disaffection from the technical field is a problem that is both more general and more serious than simple economic difficulty; it harms not only companies but also the shape of our society, equality, education and the daily lives of all people, including men. This disaffection generates: many women's technological dependence on experts (primarily males); their heightened vulnerability (and its well-known privacy concerns, among others); the invisibility on the Internet of women's history and achievements; women's exclusion from innovation and technological creation; and, women's exclusion from making the present/future society (a present/future that does not/will not consider the needs and views of women or other minorities).

Main critiques of the 'leaky pipeline' model: it is not a 'line', and 'leaks' are not failures

Although the 'leaky pipeline' model continues to function as a vehicle of mainstream research and informs policy measures aiming to promote women in computing, the model has been widely criticised. It is possible to find specific critiques of how the model tends to treat different people, fields and stages as the same (Hammonds & Subramaniam, 2003; Husu, 2001; Metcalf, 2010) or of the deficient predictions it provides and measurements it uses, such as using discrete categories of aggregated data for each stage, but presenting the 'flow' through the stages as an evolution (Metcalf, 2010). However, the best-known critiques, and those that have had greater effects on research, are those regarding the leaky pipeline model's linearity assumptions and 'supply-side' focus.

One of the most fruitful critiques is related to the linear and normative sequence of stages or steps in the pipeline image model (Bartol & Aspray, 2006b; Castaño & Webster, 2011; Jesse, 2006; Leventman, 2007; Metcalf, 2010; Soe & Yakura, 2008); these works offer an important critique both of the idea of 'a' straight normative educational pathway 'into' a technological or scientific career and of the strong distinction between education, academia and industry that this linear image implies. These studies indicate that the normative career is an abstraction that seems to occur in a social vacuum. The pipeline model neither covers the vital, educational and professional processes involved in developing a career nor contemplates the reality of alternative paths, interruptions and/or re-entries that characterise women's career trajectories (Caprile & Vallès, 2010). In line with this critique, specific contributions have been made to render visible 'multiple pathways' (Leventman, 2007), 'non-traditional pathways' (Jesse, 2006), 'non-normative' paths (Soe & Yakura, 2008) and the 'complexity of women's trajectories' (Castaño & Webster, 2011) towards ICT-related jobs and careers and towards the skills required to develop such jobs and careers.

The other most-cited critique relates to the pipeline's emphasis on the 'supply-side' focus (Bartol & Aspray, 2006b; Bennett, 2011; Jesse, 2006; Soe & Yakura, 2008; Webster, 2011). These works criticise pitfalls derived from understanding the problem of the lack of women in IT primarily as a question of how to get more girls and women to fill the pipeline. This reading of the problem usually leads to focusing the 'problem' primarily on girls' and women's lack of desire, knowledge and/or awareness of science and technological career options. Moreover, this reading is said to obscure how the 'demand' side also explains the low proportion of women and generally speaking, it asks about the cultural, structural and institutional arrangements that act, obstruct and condition girls and women's paths into IT. This reading has been important to making researchers aware that the 'problem' will be solved not only by supplying the pipeline with more women but also by changing the institutional and organisational arrangements that constitute the 'pipeline' itself (Vehviläinen & Brunila, 2007; Webster, 2011).

Furthermore, some of the critiques indicate that including the 'demand side' in the equation is not enough. Rather, there is a more substantive problematisation to be done of the 'deficit model' that frames how the problem is constructed (Abbiss, 2008; Henwood, 2000): girls and women are portrayed as 'failing' to enter and navigate the pipeline or as being deficient or deviant from a 'normal' relationship with computing in terms of their attitudes, skills, practices, interests and aspirations; girls and women are supposed to achieve a 'normal' relationship with technology – that is, boys' and men's relationship with computing. This account has been denounced as assuming that 'equality' means pushing women to conform to a 'male' standard, which not only 'conceals the relationship of the male standard to the knowledge base and therefore the institutional structures' (Markwick, 2006, p. 256) but also assumes a simplistic definition of 'equality'. Questioning this emphasis on girls and women's 'deficits' as something to be fixed is a key argument in the deeper criticism of the general liberal approach that frames the 'women in computing' field of study as a whole (Adam, 2005; Adam, Howcroft, & Richardson, 2004; Henwood, 2000; Sanz, 2010). As Adam (2005) puts it: 'Too many campaigns to persuade women to enter technical subjects have failed because of their basis in an uncontested liberalism, which fails to scratch the surface of the reasons for inequality' (Adam, 2005, p. 11). According to this point of view, not only interventions but also research fail to address the social structures that may cause the inequalities challenged by the study of women's low presence in computing.

However, and despite these significant and recurrent critiques, the dominant research remains untouched precisely in those nuclear dimensions. Mainstream research continues to document gender differences in computer uses and attitudes as the key 'barriers' to entering computing (Abbiss, 2008). Gender equality research and activities continue to focus and act both on individual women and on women's groups (Vehviläinen & Brunila, 2007), and the proliferation of initiatives devoted to changing 'girls' attitudes' towards computer science has not decreased (Fuller, Turbin, & Johnston, 2013). It has been even noted that sometimes, the question about gendered structures and cultures that characterise the pipeline is absorbed by a 'chilly climate' subset metaphor (Husu, 2001; Pawley, 2007). This metaphor provides 'superficial' solutions based on either providing 'sweaters' (mentors, for example) to girls and women to survive in such a cold place and/or promoting the implementation of programs to 'turn up the thermostat', such as a more appealing curriculum, achieving a critical mass, working conditions, support networks … (Pawley, 2007), and thus to make the environment more attractive, supportive and friendly to girls and women. In this sense, the core of the research remains untouched and the gender and computing relationship is reduced to just a 'climate' problem.

The idea that 'the pipeline metaphor communicates the "problem" to many' (Hartline, 2004, as cited in Svinth, 2006, p. 3) likely explains why it continues to be used despite the widespread critiques of that metaphor. However, it has also been claimed that we are 'trapped in the pipeline' (Hammonds & Subramaniam, 2003) in terms of the research questions that this research either allows or fosters. In the following sections, we will highlight some lines of research within the field that make other landscapes visible by shifting the questions asked and thus the eyes with which we see.

Other landscapes I: making (another) history visible

According to the established landscapes, women and computing are so persistently viewed as mutually exclusive that it is easy to feel that we are fighting a natural phenomenon. However, although this difficult relationship is visible and persistent, it is neither a universal nor a constant phenomenon. We simply must look back to change the picture. Thus, as within other academic and professional fields, the role of women as historical protagonists/actors has been largely neglected in the history of computing.

In this sense, one of the most stimulating sources for research and intervention in the field of 'women in computing' is to be found in recovering women's contributions to the field (Beyer, 2009; Gürer, 2002; Schwartz, Casagrande, Leszczynski, & de Carvalho, 2006). These works rescue and stress the names and key roles of women in the very definition and configuration of computing itself. They also help to restore women as protagonists in the history of technology and simultaneously provide 'role models'. Their pictures of past computing landscapes that contained women also allow the problematisation of biological or taken-for-granted explanations about women's under-representation in computing. Furthermore, those works not only show us that not long ago, 'computers were women' (Light, 1999) but also make us aware that computer science and computer artefacts have had women 'inside' from the very beginning.

Furthermore, there are historical-based studies that provide deeper input into problematising mainstream views and explanations. These studies avoid the common pitfall of writing a merely compensatory history of women's contributions to computing: that is, 'adding women to an existing historical framework without questioning its categories, assumptions and priorities' (Abbate, 2012, p. 5). Thus, in recent years, we can find a growing number of inspirational works focused on bringing a gender analysis to mainstream computing history (Abbate, 2012; Ensmenger, 2010; Haigh, 2010; Hicks, 2010; Schlombs, 2010). These types of works highlight the role of gender relations in the very definition and gradual configuration of computing as an activity, profession and career. Computing has been coded as a male profession not in one obvious and natural step but through co-evolving gendered and gendering processes regarding specific labour-power relations, activities, skills, identities and artefacts. Recognising that the image of computing as hostile or unattractive to women is a recent phenomenon (Hayes, 2010b) allows us to ask about the configuration of specific gender codes (Abbate, 2012) that cause us to associate a profession with particular attributes and to associate those attributes with either masculinity or femininity. Moreover, this approach allows us to situate the configuration of computing and its gendered dimensions as processes intertwined with the construction of dominant notions of 'skill', 'knowledge' and 'productivity' (Ensmenger & Aspray, 2002).

Looking to these forgotten or invisible landscapes, we gain the chance to grasp input for constructing new eyes. Instead of asking primarily 'why there are so few women in computing', these works help us continue to ask how computing has become 'masculine' and what this masculinisation tells us about the historical and social construction of computer knowledge and specialties (Ensmenger, 2010). Supplementing our works with the findings of those historical works could help us connect the changing role of women in computing with larger social processes in the configuration of computing in our society.

Other landscapes II: making non-western realities visible

There is considerable cross-national variability in the degree of male over-representation (Charles & Bradley, 2006). Some studies conducted in non-western countries show higher percentages of women studying and working in the fields of computing and ICT (Galpin, 2002). This has been reported in studies regarding Afghanistan (Hoffmann, 2010), Armenia (Gharibyan & Gunsaulus, 2006) and Mauritius (Adams, Bauer, & Baichoo, 2003). But perhaps the most-documented examples of women in computer science come from India and Malaysia.

A significant increase in the number of women pursuing a bachelor's degree in computer science has been recently described in India, where the field is even seen as being 'woman-friendly' (Varma,

2010a). Computer science and computing careers are seen as particularly suitable and attractive to women because working in front of a computer involves being indoors in an office, away and safe from the outdoor environment and concentrating on mental (not manual) tasks (Varma, 2010b). It is also seen as a good career option both for its earning potential and for the social status and prestige that it may bring (Gupta, 2012). Substantial parental support and even encouragement for this type of education has been described and has been said to give girls a strong background and high confidence in mathematics, which has also been linked to interest and persistence in computing education (Varma, 2011). In addition, science and engineering, and more specifically mathematics, are seen not as a male domain but as something in which females are taught to work hard (Varma, 2011).

In Malaysia, gender ratios in computer science education and IT industry sectors are not merely balanced – sometimes they are dominated by women (Lagesen, 2008; Mellström, 2009). On the one hand, race-based quotas endorsed by the government in the fields of education, employment and business, have opened up the option for Malay girls and women to study computer science. On the other hand, neither computing nor computer technologies seem associated with specific masculine characteristics; moreover, men do not compete for linked jobs. Again, office technologies – and specifically, indoor spaces and work settings – are closely associated with women, and outdoor work is seen as unsuitable for them. (Women who work outdoors may be 'stigmatised' as lower class.) Or, as Mellstrom states, 'The spatial segregation of what counts as female and male spaces seems to precede the gender codification of the technology' (Mellström, 2009, p. 894).

In providing the opportunity to problematise the mantra of 'there are no women in computing', those studies highlight a bias of the mainstream research question and model, thus stressing the need to include race, class or cultural milieu as central dimensions to understanding who is being marginalised in gender-IT relations.[1] Undermining the idea of a transcendental and universal notion of the masculine culture of computing provides an opportunity to dismantle both what is regarded as 'masculine' or 'not feminine' and what 'computing' is in the first instance.

Other landscapes III: making other computing sites and contributions visible

Many of the environments in which people learn, study and/or do computing do not 'officially' count as computer science. The literature on women in computing is dominated by studies and discussions of computer science education equating 'computing' with computer science degrees or studies. However, it is important not to think of 'computing' as a single educational environment or profession: Such a conception not only may hide the complexity of the situation (Hayes, 2010b) but also may foster a narrow definition of both computing and ICT in general (Clegg & Trayhurn, 2000). This narrow definition of not only computing but also ICT prevents us from seeing other educational and professional environments (those emerging from the intersection of computers and areas such as art and design, cognitive sciences, new media, biology information science and education or library science, for example) where higher percentages of women are found (Corneliussen, 2012; Cukier, Shortt, & Devine, 2002; Jesse, 2006; Vergés, 2012). For example, Vergés, Cruells, and Hache (2009) explain that more than half of the 302 women with expertise in technology that they surveyed do not had a STEM degree. Likewise, in most official statistics, other computer education sites in the social sciences, humanities, design, business studies or art (where again, one can find a higher proportion of women) are not usually counted as computer education, nor are they the focus of research of gender and computing relations (Corneliussen, 2012). These definitions marginalise and devalue women's contributions and promote the exclusion and devaluation of other disciplines, educational environments and professions that provide a richer view of what the information society is (Cukier et al., 2002) and should be. In other words, as researchers, 'we partly fail to see women's participation in computer education when ignoring the context in which they participate, denying them entry to the discourse of computing' (Corneliussen, 2012, p. 161).

Of course, we do not want to stop problematising the low proportion of women in certain areas of computer-related education.[2] However, we should remember that women are scarce in some specific dimensions and aspects of computing, and we should look at other spaces where women study, practice

and work in computing. Turning our eyes to those 'interdisciplinary' (Henwood, 2000) and 'intersectional' (Vergés, 2012) computing and IT courses and sites could not only challenge the inexorable character of our landscapes and bring visibility to alternative ways to enter computing but also further our critical understanding of gender and computing relations. Thus, research could gain from framing the inquiry through questions about how (and where) an activity is defined or counted as computing and what and who become visible or invisible through that counting.

Thus, challenging the continuing marginalisation of women in computing is not only a question of helping them to challenge 'popular' stereotypes but also a question of 'us' as researchers and educators. An awareness of not re-inscribing computing and ICT as masculine domains when taking for granted what counts as computing is a way of recognising women for the computing skills that they already have.

Other landscapes IV: making women who enjoy computing visible

The final landscape that we want to picture is one with women in computing. Even using a narrow definition of computing, it is possible to find women in computing and IT. However, we know less about those women than we know about those women who either do not enter or quit computing. Some scholars in this line have criticised the exclusion paradigm that underpins this field of studies (Faulkner & Lie, 2007; Lagesen, 2008; Mellström, 2009; Vergés, 2012; Vergés et al., 2009).

The focus on explaining what excludes women from computing and IT has been so central that inclusion processes have been largely under-researched. This does not mean that there is not a significant amount of knowledge produced that informs us about the factors that aim to explain why some women choose to enter the computer science field, what makes computing attractive for women, why some women 'persist' in those studies and how to retain women (Cohoon & Aspray, 2006; Kahle & Schmidt, 2004; Lenox, Jesse, & Woratschek, 2012; Teague, 2002). However, some scholars have noted that inclusion is treated merely as a mirror image of exclusion processes, not as a process of its own (Faulkner & Lie, 2007). In this sense, under the shadow of the leaky pipeline logic, some research shows how some factors that are said to exclude women from computing (e.g. a lack of parental or peer support, a lack of early exposure to computing and a lack of awareness about what computing is) are reversed or curbed in some biographies. In this sense, the dominant image that research provides about women who choose computer science can paradoxically reinforce 'women's exclusion' from the field. Thus, we must pay analytical attention to women who enjoy and derive pleasure from computing and programming 'in itself' (Boivie, 2010). This group also includes women who do not want to be expected to bring communicative skills, a people orientation or emotions into the picture because, as Boivie (2010) says about herself, 'I do not want to be the "bearer" of femininity, being some kind of moral compass, bringing other, better values into the area of computer science and IT' (Boivie, 2010, p. 21).

Searching for new eyes

The issues raised converge in two questions: 'What is "computing"' and 'What is "gender"?' Not surprisingly, in this field there have been other claims about the lack of theorisation related to both computing (Clegg & Trayhurn, 2000) and gender (Adam et al., 2004). However, the issue is more worrisome than a mere under-theorising: research is usually driven by strong implicit assumptions about both concepts.

In mainstream research, the deterministic account of computing and technical skills that characterises the frame used is clear. In promoting a view of computing simply as something with the 'wrong' image (particularly for girls) or a view of technical skills as skills that girls or women have more problems acquiring, technology is understood as something neutral and obvious (Henwood, 2000). Even when it is emphasised that computing and IT cultures are 'chilly' environments, the proposed interventions and strategies rely either on providing women with metaphorical 'sweaters' to survive or on implementing programs to warm up the environment and make it more friendly to women (Pawley, 2007). Thus, computing in itself is not questioned – only the 'masculine culture that surrounds' computing education and work.

We regard feminist constructivist technology studies as a more appropriate framework to challenge technological determinism. For more than two decades this perspective has been claiming that gender and technology are co-produced (Cockburn & Ormrod, 1993; Faulkner, 2001). Unfortunately, it has had little effect on mainstream research about 'women in computing'. Operationalising gender as a relevant category through which to address technologies as socially 'constructed', provides a framework to see technology as both a source and a consequence of gender relations – and vice versa (Wajcman, 2007). Gendered processes are seen as constitutive of what is recognised and valued as technology and technological expertise; simultaneously, technology is one of the ways in which gender identities and regimes are reproduced and/or transformed.

Among other contributions, this framework provides a reflexive frame in which to consider that it is not only the image of 'computing' that is masculine. Technologies 'do have gender' (Berg & Lie, 1995): from its very definition and design, and together with instructions, advertisements or associations with gendered norms, symbols and divisions of labours, gender is 'inscribed' into technologies (Oudshoorn, Rommes, & Stienstra, 2004). From a feminist perspective, gendering technologies is part of what helps maintain gendered identities and the gender power relations that characterise our society.

This framework has been presented as an important (and sometimes neglected) approach to refocusing the problem of the low presence of women in the computing field. Indeed, this approach has led to some promising approaches to gender and IT relations, particularly through studying how computer artefacts, computing practices and the computer science discipline and knowledge are gendered (Adam, 1998; Björkman & Trojer, 2006; Sanz, 2010). Asking what computer science 'is' (Björkman & Trojer, 2006) and including gender as a lens for analysis (Sanz, 2010) offers a critical evaluation of computing from its foundations, theories and methods as a discipline to its specific applications and products, showing how gendered concepts have shaped the 'content' of computer science. These works suggest that the problem of female under-representation in computing is not only a question of changing its image but also a question of reframing 'women in the computing field' as a 'gender and technology co-production' field.

Because technology is produced in a gendered world, we may reasonably suspect that gender is performing technology. However, technology is also performative for gender in the sense that gender is also produced by what a specific technology requires us to perform, through our relations with technology and the relations that it stimulates and through how it configures job and consumer markets. Unhappily, even the studies that adopt the mutual shaping of gender and technology framework keep relying on the stability of gender identity in too many occasions. While computer science and computer artefacts tend to be approached as something gendered and susceptible to having different meanings, uses and effects, gender is dealt with as a fixed and evident construction. In fact, the gender binary has been identified as a major pitfall within women in computing literature (Henwood, 2000; Landstrom, 2007). Paradoxically it has been easier to analyse computing as open to different meanings, than to open the meaning of the gendering processes, fulfilling the sort of prophecy made by Grint and Gill (1995) who identified 'blackboxing' gender as one of the risks of the meeting between constructivist perspectives on technology and feminism.

Pipeline-guided research will only contribute to reinforcing the naturalisation of gendered identities, assuming as natural the existence of women and men with different interests and needs and perpetuating the vision of male technological trajectories as both neutral and normative. As a suggestion to escape the framing limitations of the pipeline metaphor and the risk of 'blackboxing' gender, other research questions can be formulated. For example, future research could focus on how people simultaneously position themselves on the continuum from technological users to technological experts and on the femininity-masculinity continuum; and, focus on the explanations, feelings, moods, reactions, thoughts and practices when considered or considering themselves as experts in ICT who must simultaneously perform a particular gender identity when situated or situating themselves within a particular sex category (West & Zimmerman, 1987). Furthermore, more work has to be conducted to question the technological side of the equation to answer questions around the performative capacities of technology with respect to gender.

Notes

1. See Zarrett and Malanchuk (2005) for a reflection on the complex intersection of race and gender in the United States when choosing an IT career, where the educational level of parents affects black males and females in opposite directions. See also http://www.blackgirlscode.com/ for an example of a powerful activist movement which aims to tackle this issue.
2. Nor should this be confused with 'waves' of optimism regarding women's engagement in IT 'hybrid jobs', re-inscribing essentialist beliefs about the suitability of women for 'non-technical' profiles and hiding new forms of segregation or gendered pay gaps (Glover & Guerrier, 2010; Roan & Whitehouse, 2007).

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JovenTIC's goal is the study of young people's uses of, approaches to and consumption of ICT, focusing on the meanings that young people collectively construct around these practices and their relationship with the performance of identities, particularly gendered ones. On this topic, Vitores and Gil-Juárez are the authors of the following works: (1) Gil-Juárez, A., Feliu, J., & Vitores, A. (2010). Performatividad tecnológica de género: explorando la brecha digital en el mundo del video-juego. *Quaderns de psicologia*. *International Journal of Psychology, 12*, 209–226; and (2) Gil-Juárez, A., Vitores, A., Feliu, J., & Vall-llovera, M. (2011). Brecha digital de género: investigaciones e intervenciones. *TESI Teoría de la Educación, Educación y Cultura en la Sociedad de la Información, 12*, 25–53.

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